LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Center for Advanced Signal and Imaging Sciences Workshop 2004

James H. McClellan, Carmen Carrano, Lisa Poyneer, David Palmer, Kevin Baker, Diana Chen, Richard London, George Weinert, James Brase, David Paglieroni, Aseneth Lopez, Charles W. Grant, W.J. Wright, M.W. Burke, W. O. Miller, S.J.. DeTeresa, Daniel White, Aseneth Lopez, John Toeppen, Peter Haugen, Chandrika Kamath, Thinh Nguyen, Siddharth Manay, Chandrika Kamath, Shawn Newsam, Erick Cantu-Paz, Hsueh-Huan Pao, John Chang, David Chambers, Richard Leach, Christine Paulson, Carlos E. Romero, Alex Spiridon, Mark Vigars, Pat Welsh, James Zumstein, Kique Romero, Christine Paulson, John Toeppen, Alan Oppenheim, David B. Harris, Farid Dowla, Charles G. Brown, Grace A. Clark, Mike M. Ong, Todd J. Clance, laura M. Kegelmeyer, Marijn Benzuijen, Erlan Bliss, Scott Burkhart, Jim Chang, Alan Conder, Stephanie Daveler, Walter Ferguson, Steven Glenn, Judy Liebman, Mary Norton, Rahul Prasad, Thad Salmon, et al.

November 16, 2004

Disclaimer

Signal and Imaging Sciences Workshop

CASIS Workshop 2004
Abstract Proceedings
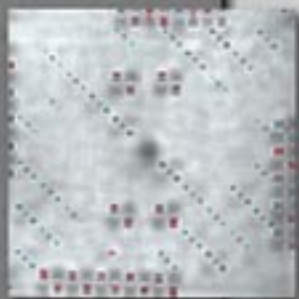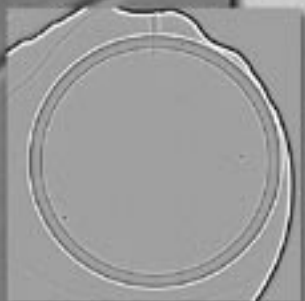
Thursday, November 18, 2004

Friday, November 19, 2004
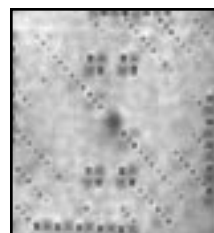
Frozen layer of deuterium and tritium inside a 2-mm diameter beryllium capsule.

Data courtesy of Bernard Kozioziemski

Image courtesy of Dan Schneberk, Darrell Rikard

Reconstructed Radar Camera image through wall-board of a person holding a rifle.

Data and image courtesy of Kique Romero

Calibration data for optics inspection.

Data and image courtesy of Laura Kegelmeyer

Welcome

Welcome to the Eleventh Annual C.A.S.I.S. Workshop, a yearly event at the Lawrence Livermore National Laboratory, presented by the Center for Advanced Signal & Image Sciences, or CASIS, and sponsored by the LLNL Engineering Directorate. Every November for the last 10 years we have convened a diverse set of engineering and scientific talent to share their work in signal processing, imaging, communications, controls, along with associated fields of mathematics, statistics, and computing sciences. This year is no exception, with sessions in Adaptive Optics, Applied Imaging, Scientific Data Mining, Electromagnetic Image and Signal Processing, Applied Signal Processing, National Ignition Facility (NIF) Imaging, and Nondestructive Characterization.

Initiated by Dr. Jim Candy, CASIS was established primarily to provide a forum where researchers can freely exchange ideas on the signal and image sciences in a comfortable intellectual environment. This workshop has become the "main event" for CASIS each year, and we are pleased to continue this tradition in 2004.

We are especially pleased to present two keynote speakers who have been among the world leaders in signal processing research and education. They have agreed to share there insights into the field as it has matured in the last half century, and to talk about their current research. Professor Jim McClellan of Georgia Tech is the recent (2004) winner of the prestigious IEEE Jack Kilby Medal in signal processing (and a former lab summer researcher in 1979!). Jim will present his recent work in array signal processing on Thursday. On Friday, Professor Alan Oppenheim of MIT will join us and speak about "Things My Mother Never Told Me (about Signal Processing)". Prof. Oppenheim is a dynamic speaker who is well known for his textbooks on digital signal processing that have educated many around the world.

We want to thank our sponsors in the LLNL Engineering Directorate (Steve Patterson, AD) for providing support for this Workshop. My personal thanks go to three people who have made this workshop happen -- Marsha McInnis, Dora DaRosa, and Deana Eshpeter. Thank you for your very hard work this year.

We hope that you enjoy the next two days of presentations, and that you find time to exchange ideas openly with the participating scientists and engineers. Thank you for attending this year's CASIS Workshop.

Stephen Azevedo
C.A.S.I.S. Director

Table of Contents

Keynote Speaker

Array Signal Processing for Locating Buried Objects and Tracking Moving Targets

Professor James H. McClellan

This talk will review recent work at Georgia Tech for two applications that involve array processing and advanced signal processing: tracking multiple maneuvering vehicles and locating buried land mines in clutter. In both problems, there is a desire to employ multiple sensor types and perform coordinated signal processing that exploits the strengths of each sensor, so some results will be shown to indicate progress along this line. However, most of our success still comes from concentrating on one sensor type at a time.

For tracking multiple maneuvering targets, we have developed a particle-filter acoustic tracker that uses a state-space update based on a locally linear motion model. By imposing smoothness constraints on the target motion, the particle filter is able to handle the multi-target data association ambiguity. Conventional wisdom says that additional sensors such as video/Infra-Red cameras or radar should enhance the robustness of the tracker. However, in a distributed micro-sensor network, additional sensors would increase power consumption, so the problem of fusing multi-modal sensor data must be done under a power-performance trade-off. We have developed a joint particle-filtering framework for tracking a target given observations from a co-located microphone array and a video camera. If the video controls the particle diversity when the SNR of the acoustics is low, the overall target tracking performance will be improved.

Detection and location of buried landmines and subsurface objects is a second application being investigated at Georgia Tech using multi-sensor systems; in this case, seismic/acoustic sensors, metal detectors, and multi-static ground penetrating radars (GPR). Images for the multi-static GPR are formed in 2-D or 3-D via conventional back-projection (migration), or its faster version, the quad-tree back-projector. Images from EMI data (metal detectors) can be made by using pole-zero modeling to find the break frequency that characterizes different metals. Seismic images are produced from reflected surface (Rayleigh) waves measured by an array of sensors on the surface. In order to produce an in situ estimate of Rayleigh wave velocity in variable soils, an algorithm for estimating the dispersion curve of the Rayleigh wave has been developed by using spatial pole-zero modeling of signals transformed to the temporal frequency domain. Two seismic imaging algorithms will be shown for processing data recorded in a lab experiment. The first, motivated by the idea of time reversal, uses the singular value decomposition of the array response matrix along with an estimate of the Green's function of the medium to image the spatial positions of near-field buried targets when wavefront curvature is significant. The second is a variation of the RELAX algorithm which performs an iterative least-squares approximation over the frequency band occupied by the Rayleigh wave to estimate both the target positions and the shapes of the reflected signals.

Collaborators: Volkan Cevher, Mubashir Alam, Ali Cafer Gurbuz, and Prof. Waymond R. Scott, Jr.

Adaptive Optics

Enhanced Surveillance Imaging

Carmen Carrano
UCRL-ABS-207847

In my talk I will give an overview of FY2004 activities and results using speckle imaging techniques for enhancing the resolution of extended scenery acquired over horizontal and slant paths through the atmosphere.

These activities included continued work on developing a near real-time speckle imaging capability and extensions of the algorithm to deal with the imaging of translating targets.

Experimental Results for
Correlation-based Wave-front Sensing

Lisa Poyneer
UCRL-ABS-207848

Correlation wave-front sensing can improve Adaptive Optics (AO) system performance in two keys areas. For point-source-based AO systems, Correlation is more accurate, more robust to changing conditions and provides lower noise. Experimental results from the Lick

AO system and the SSHCL AO system confirm this. For remote imaging, Correlation enables the use of scenes for wave-front sensing. Results from short horizontal-path experiments will show algorithm properties and requirements.

Optimal Modal Fourier Transform Wave-front Control

Lisa Poyneer
UCRL-ABS-207849

Optimal Fourier Control for Adaptive Optics (AO) is a fast and adaptive control scheme, which can significantly improve AO system performance. It uses the Fourier basis as its modal basis, allowing direct control of locations in the Point Spread Function of the AO system. Each mode is controlled individually with an optimal gain as determined from AO system telemetry.

Ultra-high Contrast Imaging Experimental Results

David Palmer
UCRL-PRES-208012

The purpose of the Extreme Adaptive Optics Coronagraph (ExAOC), currently being designed for one of the 2 Gemini 8-meter telescopes, is to image extra-solar planets; something that has never been done before. In order to do this, the system must deliver ultra-high contrast (on the order of 10_{-7}). Among other things, this requires wavefront control with many degrees of freedom. The current point-design for the ExAOC system incorporates a 4096 actuator MEMS mirror. Currently under test is a 1024 actuator version of this MEMS mirror. This presentation discusses experimental results, to date, using the 1024 actuator mirror.

Correction of Distributed Aberrations
Kevin Baker
UCRL-ABS-207887

The objective of this project is to demonstrate the use of multiple distributed wave-front correctors to enhance the functionality of optical systems with distributed aberrations. This concept is expected to provide dramatic improvement in the optical performance of systems in a variety of applications where the aberrations are distributed along the optical path. Several systems will be discussed. One application is the use of multiple deformable mirrors to correct internal aberrations within the Large-Aperture Synoptic Survey Telescope (LSST). A separate application is the use of several deformable mirrors to improve the corrected field-of-view for multi-conjugate adaptive optics systems, in this case to correct for distributed atmospheric turbulence. The final application discussed is the use of two deformable mirrors to correct both phase and amplitude variations in an optical system, which can be important for short pulse laser systems and for AO systems requiring Strehl ratios greater than 0.8 such as extreme adaptive optics systems.

Ophthalmic Imaging with Adaptive Optics
Diana Chen
UCRL-ABS-207941

Conventional ophthalmic instruments provide basic imaging of human retina, but with limited resolution. The adaptive optics group in LLNL is working on developing new ophthalmic imaging instruments such as flood-illumination system, scanning laser microscope and optical coherence tomography with adaptive optics. These novel instruments provide capabilities to visualize photoreceptors, nerve fibers, flow of white blood cells, etc. for disease studies and clinical treatments. Experimental results show that both resolution and contrast of retinal image have been increased significantly.

Applied Imaging

Nonlinear Structured Illumination Microscopy

Eugene Ingerman, UC Davis, Richard London, LLNL, Mats Gustafsson, UCSF
UCRL-ABS-207858

The structured illumination method allows one to increase the lateral resolution in widefield fluorescent microscopy by a factor of two. The use of nonlinear fluorescent dyes with this method would allow one to improve the resolution even further. We will present the results of numerical simulations with one and two dimensional illumination patterns and discuss the expected resolution improvements.

Computer-Aided Content-Based Cueing of Remotely Sensed Images with the Image Content Engine (ICE)*

George F. Weinert, James M. Brase and David W. Paglieroni
UCRL-ABS-202618

Human analysts are often unable to meet time constraints on analysis and interpretation of large volumes of remotely sensed imagery. To address this problem, the Image Content Engine (ICE) system currently under development is organized into an off-line component for automated extraction of image features followed by user-interactive components for content detection and content-based query processing. The extracted features are vectors that represent attributes of three entities, namely image tiles, image regions and shapes, or suspected matches to models of objects. ICE allows users to interactively specify decision thresholds so that content (consisting of entities whose features satisfy decision criteria) can be detected. ICE presents detected content to users as a prioritized series of thumbnail images. Users can either accept the detection results or specify a new set of decision thresholds. Once accepted, ICE stores the detected content in database tables and semantic graphs. Users can interactively query the tables and graphs for locations at which prescribed relationships between detected content exist. New queries can be submitted repeatedly until a satisfactory series of prioritized thumbnail image cues is produced. Examples are provided to demonstrate how ICE can be used to assist users in quickly finding prescribed collections of entities in overhead images.

Phase-Based Road Detection in Multi-Source Images

Aseneth Lopez
UCRL-CONF-204778

The problem of robust automatic road detection in remotely sensed images is complicated by the fact that the sensor, spatial resolution, acquisition conditions, road width, road orientation and road material composition can all vary. A novel technique for detecting road pixels in multi-source remotely sensed images based on the phase (i.e., orientation or directional) information in edge pixels is described. A very dense map of edges extracted from the image is separated into channels, each containing edge pixels whose phases lie within a different range of orientations. The edge map associated with each channel is de-cluttered. A map of road pixels is formed by re-combining the de-cluttered channels into a composite edge image which is itself then separately de-cluttered. Road detection results are provided for DigitalGlobe and TerraServerUSA images. Road representations suitable for various applications are then discussed.

Anticipated Data Structures and Algorithms for Use with Graph Based Remote Sensed Image Content Storage and Retrieval

Charles W. Grant
UCRL-ABS-

ABSTRACT NOT RECEIVED BY AUTHOR

Infrared Imaging to Quantify Temperature Changes During Rapid Materials Deformation

W.J. Wright, M.W. Burke, W.O. Miller, and S.J. DeTeresa
UCRL-ABS-207413

The goal of this work is to study the partitioning of energy dissipation during dynamic deformation and failure of metals and polymers using infrared imaging. Understanding this partitioning of energy is critical to predicting the material response, specifically the temperature rise and subsequent softening, localization, and failure that can occur under dynamic loading. Contact method temperature measurement techniques such as thermocouples lack the response time and spatial resolution required to characterize materials deformation processes that occur on the timescale of microseconds with characteristic dimensions of microns. Infrared thermography provides full field imaging capability with the required spatial resolution; however, the intensity of the infrared signal as a function of temperature must be calibrated for each material of interest. Experimental parameters such as the surface emissivity of the target and the influence of the surrounding environment will be discussed. Results for the temperature increases sustained by tantalum under uniaxial compression at intermediate strain rates (10 s^{-1}) will be presented.

The Search for Classical Helike

Sean Lehman

In 373 BC an earthquake and tsunami destroyed and submerged the classical Greek city of Helike (HELL-E-KEY) on the southwest shore of the Gulf of Corinth. In August and September 2000, a scientific team directed by the Greek archaeologist Dr. Dora Katsonopoulou, President of the Ancient Helike Society, and Dr. Steven Soter of the American Museum of Natural History in New York, discovered the first evidence for the location of Helike. In June 2004, we performed seismo-acoustic subsurface imaging to aid the archeologists in their search for the city by determining excavation locations.

Simulation of Magnetic Resonance Imaging Eddy Currents using EMSolve

Daniel White
UCRL-ABS-208020

Magnetic Resonance Imaging (MRI) is a powerful non-invasive imaging technique that is playing an increasingly important role in medicine. MRI is considered harmless, it can be tuned for imaging specific chemicals, and it has higher resolution and contrast than competing imaging modalities. Automatic segmentation and classification algorithms require very high quality images, and hence MRI research-ers are still trying to improve upon the quality of the images. In this talk we will discuss electromagnetic eddy currents and how they may effect the quality of MRI images. We will illustrate how the LLNL EMSolve code has been used to simulate RF eddy currents, and we will speculate on how knowledge of the eddy currents can be exploited to produce higher quality images.

Scientific
Data Mining

Comparing Simulations to Experiments: Early Experiences

Chandrika Kamath and Thinh Nguyen

UCRL-ABS-207760

We present some early results in comparing simulations to experiments. Using techniques from image processing, we show how denoising can be used to remove structured noise in experimental images. These images are then processed to identify objects and extract features which can be used in comparing simulations to each other or to experiments.

Low Level Methods in Image Data Enhancement

Siddharth Manay and Chandrika Kamath

UCRL-ABS-207429

We demonstrate several methods for image enhancement that rely on pixel level operations to enhance the visibility of low contrast features in data on regular grids. These include edge sharpening and contrast enhancement with adaptive histogram and Retinex methods. We extend these methods to highlight interesting phenomena in experimental and simulation data.

Comparing Shape and Texture Features for Pattern Recognition in Simulation Data

Shawn Newsam
UCRL-ABS-207325

Shape and texture features have been used for some time for pattern recognition in datasets such as remote sensed imagery, medical imagery, photographs, etc. In this work, we investigate the use of these features in simulation data. In particular, we explore which features are suitable for characterizing regions of interest in a similarity retrieval framework.

Feature Selection in Scientific Applications

Erick Cantu-Paz, Shawn Newsam, and Chandrika Kamath
UCRL-ABS-207635

Numerous applications of data mining to scientific data involve the induction of a classification model. In many cases, the collection of data is not performed with this task in mind, and therefore, the data might contain irrelevant or redundant features that affect negatively the accuracy of the induction algorithms. In this presentation, we describe applications of efficient feature selection methods to data sets from astronomy, computer simulations, and remote sensing. We use variations of recently proposed filter methods as well as traditional wrapper approaches where practical. We discuss the importance of these applications, the general challenges of feature selection in scientific datasets, the strategies for success that were common among our diverse applications, and the lessons learned in solving these problems.

Electromagnetic Imaging and Signal Processing

Moving Vehicle Characterization Using Ultra Wide Band (UWB) Radar

Peter Haugen
UCRL-ABS-208039

A hardware and software system is being designed and built for the automated detection and identification of vehicles moving along a transportation corridor. The final system has requirements constraints on power, and deploy-ability. The system must collect sufficient information from sensors to be able to autonomously characterize attributes such as: vehicle presence, count, location, direction, speed, and type.

This talk will cover a number of the unique challenges pertaining to the use of UWB techniques to meet the requirement needs. First, the sensor restrictions and selection process used which resulted in UWB radar as the chosen system. Followed by a description of how the data collection and field-tests were performed, including integration with ground-truth devices (cameras, laser radar) used to establish a baseline for data processing. Finally, what the collected data looks like and what types of signal processing were preliminary applied to extract the desired information.

Probability Density Function for Waves Propagating in a Straight PEC Rough Wall Tunnel

Hsueh-Yuan Pao,
UCRL-PROC-202082

The probability density function for wave propagating in a straight perfect electrical conductor (PEC) rough wall tunnel is deduced from the mathematical models of the random electromagnetic fields. The field propagating in caves or tunnels is a complex-valued Gaussian random processing by the Central Limit Theorem. The probability density function for single modal field amplitude in such structure is Ricean. Since both expected value and standard deviation of this field depend only on radial position, the probability density function, which gives what is the power distribution, is a radially dependent function.

Keynote Speaker

Things My Mother Never Told Me (About Signal Processing)

Professor Alan V. Oppenheim

There are many styles for doing research both at an academic institution and in industry. This talk will share some personal thoughts that have been important to me in my research and teaching career and that I try to convey to my students about doing creative research. (One of my favorites is "when in doubt, go skiing".) The talk will also discuss some of the current projects underway in the Digital Signal Processing Group (DSPG) at MIT and how we happened to choose them.

Electromagnetic Imaging and Signal Processing

Ultrawideband Imaging at Multiple Frames-per-second

Principal Investigator: John T. Chang (Engineering)
Co-investigators(LLNL): Stephen G Azevedo*, Dave Chambers*,
Peter Haugen*, Richard R Leach*, Christine Paulson#,
Carlos E Romero*, Alex Spiridon*, Mark Vigars*,
Pat Welsh*, James Zumstein*

ABSTRACT NOT RECEIVED BY AUTHOR

UWB Through Wall
Data Analysis

Kique Romero

ABSTRACT NOT RECEIVED BY AUTHOR

Calibration Procedures for Picosecond Electronic Beam-steering

Christine Paulson

UCRL-ABS-207954

The MIR Radar Camera is a portable, real-time imaging system capable of identifying targets behind smoke, walls and other obstructions. By combining a precise digital timing system with an array of Micro-power Impulse Radar transmitters and receivers, high precision electronic beam-steering is achieved. This presentation will provide an overview of implementation challenges currently faced in the development of the MIR Radar Camera. Specifically, sources of timing error and calibration techniques will be addressed.

Stereo Vision — A Method of Seeing and Measuring Depth

John Toeppen

ABSTRACT NOT RECEIVED BY AUTHOR

Applied Signal
Processing

Subspace Detection
in Seismology

David B. Harris

UCRL-ABS-207903

Current practice in seismic event detection is concentrated at the extremes of a spectrum of possibilities determined by the degree of knowledge available about the signals to be detected. At one end of the spectrum, information is available about only the frequency content of the signal. Correspondingly, simple energy detectors operating in fixed passbands are the detection method of choice. This approach is the seismological standard for detection of events over broad regions. At the other end of the spectrum, the signal is completely known. For such cases, correlation detectors (matched filters) are indicated. Correlation detectors are the emerging standard for detection of repetitive events from sources with very limited geographic extent (a few wavelengths), e.g. mines, compact earthquake swarms and aftershock sequences. It is desirable to seek detectors that operate between the extremes, i.e. that have much of the sensitivity of correlation detectors, but more of the flexibility of energy detectors to detect signals with greater uncertainty. Subspace detectors offer one approach to achieving this tradeoff. This talk describes an application of subspace detectors to detect events in a swarm wit significant signal variability.

Giga- and Tera-Hertz Radio Frequency
(RF) Research Initiatives at LLNL

Farid Dowla

ABSTRACT NOT RECEIVED BY AUTHOR

Application of Cepstrum-Based Phase Retrieval to Lightning Safety Studies of Explosive and Weapons Storage Facilities

Charles G. Brown Jr., Grace A. Clark, Mike M. Ong, Todd J. Clancy

UCRL-ABS-207505

Lightning strikes to weapons storage facilities can generate high voltages and induce large electromagnetic fields within those facilities, possibly adversely affecting systems stored inside. Hence, determining the electromagnetic environment due to lightning attachment is critical for the safe operation of explosive and weapons storage facilities.

One option for determining the electromagnetic environment due to a lightning attachment is to inject current into the facility and then measure the resulting interior electromagnetic fields and calculate interior voltages. Since injecting high, lightning-like currents is difficult and dangerous, in most cases, especially with operational storage structures, low-amplitude currents are the only option. In one low-amplitude method, a linear time-invariant system model for the building is assumed, which is a reasonable model for this problem. Sinusoidal currents are injected at a likely lightning strike point on the building and swept over the dominant frequency range of the typical lightning current. Inside the facility, the resulting electric field is measured. The measurements are used along with a system identification methodology to develop a frequency response of the structure, which is a transfer function that relates the exciting current to the resulting internal electric field. Multiplication of the frequency response by the Fourier transform of a simulated high-amplitude lightning current pulse, and then inverse transforming the product, gives the time-domain electric field response to that current pulse. The electric field is used to calculate the maximum expected voltage potential in the facility. Storage safety procedures are then developed based upon this maximum expected potential.

This straightforward signal processing approach is complicated by the realities of practical measurement systems. The above approach requires both magnitude and phase measurements. However, phase is difficult to measure in this type of experiment without corrupting the results, so it is not always available. Such is the case in a recent lightning safety campaign for Site 300.

In this presentation, we describe preliminary results of applying cepstrum-based phase retrieval techniques to lightning safety measurements for Site 300. We compare the results to both simulated and measured data. Even though our results pertain particularly to Site 300, we believe the methods presented have more general application to all lightning safety studies that use similar measurement methods.

National Ignition Facility Imaging

Overview: NIF Optics Inspection Analysis and Verification

Laura M. Kegelmeyer, Steve Azevedo, Marijn Bezuijen, Erlan Bliss,
Scott Burkhart, Jim Chang, Alan Conder, Stephanie Daveler, Walter Ferguson,
Steven Glenn, Judy Liebman, Mary Norton, Rahul Prasad and Thad Salmon
UCRL-ABS-207502

The NIF Optics Inspection Analysis System has been developed over the past several years to automatically find aberrations in images of optics before and after they are installed on the NIF beamline as well as while they are in situ on the beamline. Having a unified system allows us to track the condition of an optic throughout its lifetime.

This overview will introduce the 10 different inspection types and demonstrate the unified tracking and visualization capabilities of the automated optics inspection analysis system. Lastly, we introduce new methods for calibrating and validating our Optics Inspection analysis results.

Efficient Detection of Objects of Unknown Size and Shape in Noisy Images

Marijn Bezuijen, Laura Mascio Kegelmeyer, Judy Liebman
UCRL-ABS-207500

In image processing, the detection of objects in an image is a very common problem. All existing solutions we found make assumptions about either the size of the objects, the shape of the objects or characteristics of the background image such as noise levels and smoothness. In developing an automated inspection system for the NIF optics, we found that these assumptions did not hold for these images and the objects of interest. Noise levels and background properties can vary wildly even within a single image. Objects of interest ranged from sub-pixel sizes to thousands of pixels.

While these objects are clearly visible to a person trained to look for them, no existing algorithm would work. The first prototype we developed estimates the signal to noise ratio for each pixel or set of pixels in an image, as compared to its surroundings. It was found that an algorithm based on this method could distinguish objects of interest from the background in many different types of images, given the right parameters for each type of image.

We have now developed and successfully tested an implementation of this algorithm that is completely based on full-image logic, which greatly improves the speed of the detection process. Furthermore, this has been extended to look for objects at all scales that could possibly exist in the image, without a severe speed penalty.

The algorithm will be verified to comply with the existing code in NIF and will eventually allow the extension of the optics inspection to all 192 NIF beam lines.

Image Registration for NIF Optics Inspection

Judy Liebman, Laura Kegelmeyer, Marijn Bezuijen

UCRL-ABS-207501

One of the major challenges for the NIF Optics Inspection Analysis System is inspecting optics that are closely spaced within a NIF beamline. The "final optics" before the target chamber, in particular, are difficult to inspect because they are closely spaced, transparent and some are non-uniformly thick. Our illumination source is a CW laser that travels downstream, while our camera is effectively at target chamber center and looks upstream. This means that an aberration that occurs on one optic will be visible, but more or less out-of-focus when the camera focuses on any of the other optics in the final optics set. In order to apply a focus metric and calculate which optic a feature most likely resides on, the optics inspection software must first register the images to determine comparable points.

In this talk we discuss the problem of registering the final optics images. The main difficulty is that a high percentage of the features in each image do not have matching features in other images. These outliers bring the data near the 'breakdown point' where it becomes impossible to distinguish inlier correlations. In order to be robust to outliers and to feature perturbation errors between images, a feature-based matching method is chosen over whole image correlation. The three components of most feature-based registration techniques are: feature detection, feature matching, and transform model estimation. One portion of our solution is based on these feature registration components. In addition we have developed a novel algorithm that combines the feature matching and 2D transformation estimation steps. This algorithm is based on the Hough transform voting concept and is therefore robust to noise and can handle large transformations. The algorithm finds approximate x and y offsets without requiring the unknown feature matches. We have been successful at correlating final optics images using a combination of these two approaches.

Finally, this talk will include a preview of adapting the vote-based algorithm into a method that can robustly find large 4D (x offset, y offset, magnification, rotation) transformations, as well as a preview of a probabilistic walking method for finding 4D (x offset, y offset, x magnification, y magnification) transformations that we are evaluating.

NIF Beam Noise – Characterization and Simulation

Omar Hafiz and Walter Ferguson

ABSTRACT NOT RECEIVED BY AUTHOR

Detection of Off-normal Images for NIF Automatic Alignment

Wilbert McClay, Abdul Awwal, James Candy,
Walter Ferguson, Karl Wilhelmsen, Scott Burkhart
UCRL-ABS-207840

The National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory is under construction to precisely focus 192 laser beams on a nanoscale target capsule to achieve fusion. The automatic alignment system developed for NIF is used to tightly position the beams in order to achieve the required focusing. However, if a distorted image is inadvertently created by a faulty camera shutter or some other potential malfunction the resulting "off-normal" image must be effectively detected and rejected.

In this presentation we discuss the development of an "off-normal" pre-processor capable of rapidly detecting the off-normal images and performing the rejection. We show the overall design concept for the pre-processor and then choose the corner-cube alignment loop to demonstrate the detection. Since the algorithm is only required to provide a screening function, the underlying goal of the design is to keep the detection scheme as simple and fast (e.g. row/column averaging) as possible without having to perform the actual image alignment processing (e.g. centroiding). The pre-processor is shown to be capable of detecting a wide variety of off-normal images and performing the rejections reliably. Performance analysis of the particular algorithm is demonstrated.

Two-step Position Detection for NIF Automatic Alignment

Abdul Awwal
UCRL-ABS-207774

One of the important tasks in aligning 192 laser beams at the National Ignition Facility(NIF) at Lawrence Livermore National Laboratory is finding the position of the beams using automated image processing of video images. The real beam must be aligned to positions established by other reference beams. To distinguish between various beams such as reference or main beams, markers of various shapes and sizes may be used. Matched filtering is a robust technique to identify these markers in the presence noise.

One is faced with the challenge of determining the appropriate matched filter to use in the presence of distortions, marker size and type variability. An incorrect filter will result in significant position uncertainty or long processing time. Thus in the first step of position detection one has to come up with an automated process to select the right template to use. The automated template identification method proposed here is based on a two-step approach. In the first step an approximate classification of object is determined. Then the filter is chosen based on the best template size within the class. Real world examples of the application of this technique from NIF are presented.

33

Nondestructive Characterization

Simulation of Phase Contrast Imaging for Mesoscale NDE

Maurice B. Aufderheide, Anton Barty, and Harry E. Martz, Jr.
UCRL-ABS-203786

High energy density experiments, such as those planned at the National Ignition Facility (NIF), use mesoscale targets with the goals of studying high energy density physics, inertial confinement fusion, and the support of national security needs. Mesoscale targets are typically several millimeters in size and have complex micrometer-sized structures composed of high-density metals and low-density foams and ices. These targets are designed with exacting tolerances that are difficult to achieve at present. Deviation from these tolerances can result in compromise of experimental goals and thus it is necessary to determine as-built properties of these targets using NDE techniques. Phase contrast radiography and computed tomography are being used to investigate these targets, but the mix between phase and absorption information is difficult to separate, making interpretation of results difficult. We have recently improved the HADES radiographic simulation code to include phase in simulations, as an aid for doing NDE on mesoscale targets. In this paper we report on how we extended HADES to incorporate phase contrast, and compare simulations with a variety of experimental test results.

Applying Terahertz Imaging at LLNL

Michael W. Burke

ABSTRACT NOT RECEIVED BY AUTHOR

Impulse Response Estimation for Spatial Resolution Enhancement in 3D Ultrasonic Nondestructive Evaluation Imagery

Grace A. Clark (LLNL/EE/EETD, Steven E. Benson (LLNL/ME/MMED)

UCRL-ABS-207826

Generally, one of the major desired results from a Nondestructive Evaluation (NDE) test of a mechanical part is a segmented image or a 3D image cube showing the locations and physical characteristics of cracks, inclusions, voids, delaminations, ablations and other flaws. A key NDE goal is to obtain images having the best possible spatio-temporal resolution. Unfortunately, the resolution of all ultrasonic measurements is severely limited by the inherent fundamental band-limited spectral transfer function of ultrasonic transducers, the uncertainty principle and the diffraction limit. In the time domain, the transducer causes severe ringing, which greatly limits resolution.

We present a system identification algorithm and a MATLAB-based software / hardware system for improving spatial resolution in 3D rendered ultrasonic NDE images. Given a measured reflection signal (A-scan) and an associated reference signal, the algorithm produces an optimal least-squares estimate of the impulse response of the material under test. The estimated impulse response, when used in place of the raw reflection signal, enhances the spatial resolution of the ultrasonic measurements by removing distortion caused by the transducers and the materials under test.

By applying the impulse response estimation algorithm to all available A-scan (1D) measurements, we obtain improved-resolution renderings of B-scans (2D vertical slices), C-scans (2D horizontal slices) and 3D image cubes. We demonstrate the 3D rendering system and resolution enhancement results using example measurements from (1) controlled experiments with known material samples, and (2) Lab programmatic material samples.

Progress Towards an Electro-acoustic Resonance Technique for Determining Quantitative Material and Geometrical Properties in High Contrast Multi-layer Elastic Structures.

Karl A. Fisher

UCRL-ABS-207757

High contrast multilayered elastic structures routinely encountered in the NDE section at LLNL continue to be the 'bane' of ultrasonic inspection. Large acoustic material impedance mismatches, refraction, reverberation, multiple echoes, and high elastic attenuations are just some of the issues one is faced with standard high frequency (1- 20MHz) pulse echo detection and imaging methods. In this presentation, we will present progress towards developing a low frequency resonance technique that operates in the (20 – 70 kHz) regime. The technique is based on a direct correlation between the electrical impedance of a standard electro-acoustic transducer and the mechanical loading it experiences when placed in contact with a layered elastic structure. Preliminary experimental and theoretical results are in good agreement.

Inspecting Layers of Interest in a Multilayered Structure Using Guided Waves

M.J. Quarry

UCRL-ABS-20717

Many programmatic applications involve structures comprised of multiple layers, such as weapons systems and NIF targets. Ultrasonic guided waves offer a powerful inspection method that can efficiently inspect inaccessible areas without disassembly. Exciting modes with energy in the layer of interest is essential. Suitable modes are excited using an array with the proper spatial characteristics that is also phased on reception. Results will be presented that show the quantitative abilities of the technique. Guided waves also propagate around curves and bends. Flaw detection on curved multilayer structures will be shown. The technique is also scalable to different thicknesses and curvatures as will be discussed with modeling and experimental results on small tubes.